https://research.stmarys.ac.uk/

TITLE
The identification of hip and knee dominance in professional football players using various gym based exercises

AUTHOR
Mulroy, John A.

DATE DEPOSITED
2 September 2016

This version available at
https://research.stmarys.ac.uk/id/eprint/1153/

COPYRIGHT AND REUSE
Open Research Archive makes this work available, in accordance with publisher policies, for research purposes.

VERSIONS
The version presented here may differ from the published version. For citation purposes, please consult the published version for pagination, volume/issue and date of publication.

The identification of hip and knee dominance in professional football players using various gym based exercises

Principle Researcher: John A. Mulroy

Project Supervisor: Daniel Cleather

June 5th 2016

This Research Project is submitted as partial fulfilment of the requirements for the degree of Master of Science, St Mary's University

Table of Contents

List of Figures

List of Tables

Acknowledgements

The author would like to thank Reading F.C. for use of their facilities and Jack Lynham for his assistance throughout the year. The author would also like to thank Dan Cleather for his help on the IDA model and feedback on my first draft. This would not be possible if it weren't for the support of my family and girlfriend, thank you all very much.

Abstract

Athletes perform movements by loading their joints in different ways. The aim of this study was to determine whether athletes used a common loading strategy across various gym based exercises and to further understand the mechanical differences seen between these exercises. Seven male professional football players (age (19.43±0.98; height 1.84±0.07 m; weight 80.21±7.58 kg) were asked to perform an unloaded countermovement jump (CMJ), forward lunge, single leg countermovement jump (SLCMJ), deadlift and goblet squat. A portable force plate and high speed camera collected kinetic and kinematic data for each subject at 250 Hz during the propulsion phase of the exercises. A 2-D inverse dynamics model was used to calculate the joint moments at the hip and knee. Bonferroni post hoc analysis revealed no significant differences between mean hip: knee ratios and CMJ, lunge, SLCMJ, deadlift and goblet squat exercises. Two loading patterns were observed among all the exercises. The first was a hip dominant strategy (i.e. hip moments 10% greater than knee moments) which was observed in all subjects for the lunge exercise only. The second was a knee dominant strategy (i.e. knee moments 10% greater than hip moments) which was found for the rest of the exercises. The mean hip moment scores of the subjects were significantly greater in lunge compared to the CMJ, deadlift and squat. The mean knee moment scores of participants in the SLCMJ was significantly higher compared to the knee moments experienced in the squat and deadlift. Results suggest no differences existed between subjects but rather a difference existed between exercises. Coaches can use this information to select appropriate exercises that can develop either hip or knee loading in their athletes.

Key Words: inverse dynamics, joint moments, exercises, specificity, ratio

Chapter 1

INTRODUCTION

Understanding the cause of movement, the mechanisms involved and the movement strategies different athletes adopt can help strength and conditioning coaches design the most individualised programmes that can target specific areas of adaptation. Of specific importance to coaches, the internal forces that act on a particular joint can tell coaches what joints are being loaded too much or too little during an exercise. Due to advancements in biomechanics, internal forces can be calculated through many different kinetic analyses. One form of kinetic analysis, known as inverse dynamics analysis (IDA), can predict the summation of all intersegmental muscle forces acting about a specific joint (20,31) and allow researchers to make definitive interpretations on the mechanical characteristics of both athlete and exercise. The transfer of specificity from an exercise to a sports skill depends upon many different rules, one of which is the mechanical similarity between both the exercise and the sports skill (29). It is also dependent on how the athlete performs the exercise as the transfer of specificity may be lost if the athlete performs the exercise in a mechanically different way. Therefore understanding both the specific causes of movement during an exercise and the specific individual movement strategies can allow coaches to better select appropriate exercises for their athletes.

Studies that have used kinetic analyses have increased practitioner's understanding of the mechanical similarity between gym based exercises and sports skills (16,18). There have been plenty of researchers that have described the biomechanics of the squat (9,13,24,25), forward lunge (11,23)

CMJ (6,17,27) and deadlift (8,26) exercises. By calculating joint moments, the product of force and the perpendicular distance from the centre of mass, researchers can assess the relative contribution that each joint has on the performance during an exercise. Research has suggested that athletes can perform exercises in different ways by loading their joints differently (5, 23, 26). During performance of movements such as running or jumping certain athletes load their hip joint more than their knee joint and vice versa. There are also some athletes that are more balanced, who load their joints equally in order to perform a movement. An athlete that predominately loads their hip over their knee is thought to be hip dominant athlete and vice versa (5,14). Cleather et al., (5) suggested using a difference of 10%, therefore a hip dominant athletes would have 10% higher hip moments compared to knee moments. Anywhere in between would represent a balanced strategy. The importance of knowing what loading strategy athletes prefer to use is twofold. Firstly, coaches can understand their athlete strengths and weaknesses. By knowing whether or not an athlete is hip or knee dominant, this can aid in the selection of more appropriate training goals. Secondly, and most importantly, if a sports skill requires greater loading at the hip e.g. top speed running, an athlete who is knee dominant may be at a disadvantage compared to a hip dominant athlete.

In order to calculate hip and knee dominant athletes, a ratio method is used to determine the differences between hip and knee moments i.e. hip: knee. This type of method for comparing loading between joints has been used previously in the literature, most notably between quadriceps and hamstring strength (8). This method aids in the screening of athletes for risk of anterior cruciate ligament (ACL) injury. It has also been recommended by Goodwin (14) to use ratios for two reasons. Firstly, its use can provide coaches with a snapshot of the strengths and weaknesses of their athlete in an easy to use method. Secondly, it allows coaches to easily track changes in their programme over the long term. Ratios can be used to compare any two variables and in this study the hip and knee moments are used and a hip: knee ratio was calculated from these measures. Goodwin (14) had suggested that the ratio between squat and deadlift can determine if the athlete was hip or knee dominant however this study aimed to use a more accurate representation of the actual loading strategy seen at the hip and knee for each athlete by measuring the internal net joint moments. This allows the author to more accurately predict if an athlete is in fact hip or knee dominant.

The purpose of this research project was to use a 2-D IDA to predict the internal kinetics of both the hip and knee and then provide coaches with an easy to interpret ratio method to determine if athletes are hip or knee dominant. The first aim of this study was to identify if differences existed between subjects for hip and knee ratio. It was predicted that some subjects would be knee dominant while other subjects would be hip dominant. A secondary aim of this study was to add to the growing body of research that describes the net joint moments of the hip and knee during various gym based exercises. This would allow coaches to better understand both the loading strategy of both athlete and exercise which can lead to more appropriate exercise selection in future programmes.

Chapter 2

METHODS

Experimental approach to the problem

This study was designed to identify whether athletes adopt a common loading pattern among various gym based exercises. Further to this, this study added to the growing research that describes the internal joint moments of the CMJ, SLCMJ, forward lunge, deadlift and goblet squat. Kinetic and kinematic data were collected using a portable force plate and high speed camera. All data was inputted into a 2-D IDA model to identify ankle, knee and hip moments. In order to test the hypothesis all data was normalised to body weight and a hip: knee ratio was determined for all exercises.

Subjects

Seven male professional football players were recruited from Reading F.C for this study. Subject anthropometrics were (mean ± SD): age (19.43±0.98 years), height (1.84±0.07 m) and body mass (80.21±7.58 kg). Subjects who had at least one year training history and experience of performing the exercises used in this study were included. Subjects were required to be free from any musculoskeletal injury or illness in order to take part. Each subject was supplied with a plain language information sheet, consent form and verbal instructions which outlined in detail the study design, purpose and any risks that may be involved. Each subject signed the consent form and returned to the investigator prior to commencement of the study. Ethical approval was permitted from the ethical review board of St. Mary's University.

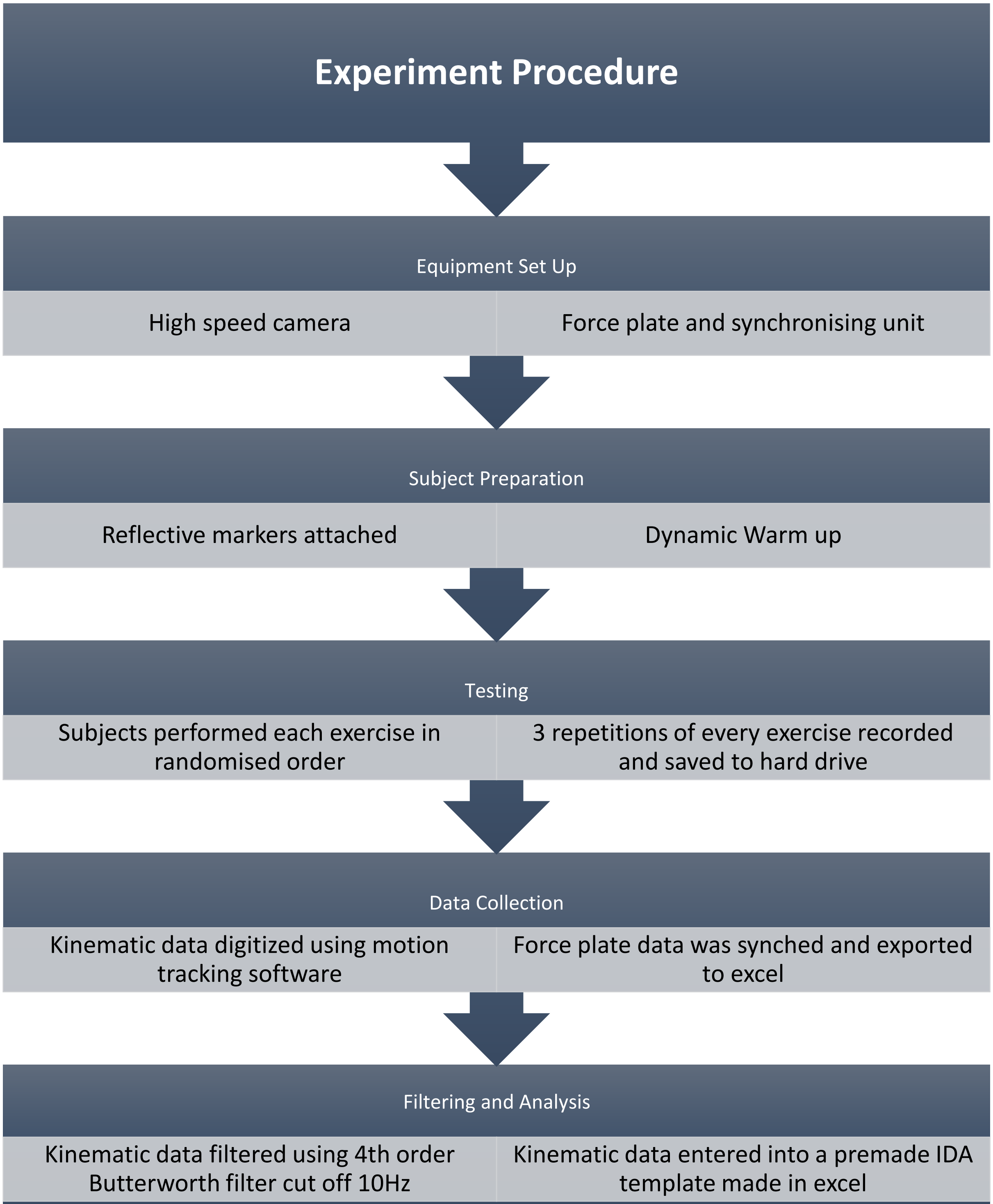
Instrumentation

Reflective markers were placed by the author on anatomical landmarks on the right hand side of each subjects' body. The anatomical sites included the shoulder (acromioclavicular joint), hip (greater trochanter), knee (lateral ridge of tibial plateau), ankle (lateral malleolus), and distal end of the foot (metatarsus head) (31,32). Using a high speed camera (Phantom v9.0.663, Vision Research Inc, Wayne New Jersey, USA), kinematic data was collected at 250Hz during each of the exercises. The camera was mounted on a tripod, manually triangulated using two measuring tapes, and positioned perpendicular to the subject 10m away. The high speed camera was manually adjusted for shutter speed, focus and alignment to position the image in the centre of the camera. Two objects of known length located close to the centre of the field of view were used convert pixels into real world units using the motion tracking software. Kinematic data was then digitized using Kinovea (Version 0.8.15) and later filtered using a fourth order Butterworth filter with a cut off frequency of 10Hz in Excel (Microsoft Office 2013). The filtered data was entered into a premade IDA model to calculate the net joint moments at each joint. Ground reaction force data was also recorded using a portable uniaxial force plate (PASPORT Force Platform PS-2141, PASCO, Roseville California, USA) sampled at 250Hz, with dimensions of 35cm (length) x 35cm (width). The force plate contained four sensors at each corner 31cm (length) x 25cm (width). Each sensor was summed to produce a ground reaction force in the vertical direction. All forces were entered into a calculation to determine centre of pressure. The kinematic and kinetic data was synchronised using an external synchronisation unit. The synchronisation unit was a small box that was attached to the force plate and once triggered emitted a light source as well as sending a voltage into the force plate. This was sampled at 1000Hz. The filtered kinematic data and the kinetic data was entered into a premade IDA model to calculate the net joint moments at each joint.

Procedure

An overview of the experimental procedure can be seen in Figure 1. Subjects were attached with reflective markers and then brought through a 10 minute dynamic warm up finishing with practise of the exercises. The reflective markers were attached to the subject, using tape, by estimating the joint centre. A trained physiotherapist assisted the author with the location of each joint centre. After the warm up each subject was recorded performing three repetitions of every exercise. Subjects stood perpendicular to the camera and to the left of the force plate which allowed only the right leg to be recorded. Subjects were asked to perform each exercise the same way they would normally in the gym.

Figure 1.



The exercises used in this study are described below:

The Goblet Squat:

Subjects stood on the force plate, with the right leg only, feet hip width apart. The left leg was placed on a wooden board that was flush with the force plate. While holding a kettlebell by their chest, subjects were asked to flex at the ankle knee and hip until a self-selected depth was achieved. Subjects returned to the start position by extending through the hip, knee and ankle. Three repetitions were performed with a self-selected rest between repetitions. Figure 2 displays the start and finish position of the squat.

Figure 2.

The Deadlift:

Subjects were required to flex at the ankle, knee and hip until they could grasp the kettlebell, which was placed under their hips. While keeping arms straight, subjects extended through the hip, knee and ankle to bring the kettlebell off the floor. They then flexed through the hip, knee and ankle to return the kettlebell to the starting position. Three repetitions were performed with a self-selected rest between repetitions. Figure 3 shows start middle and end positions of the deadlift.

Figure 3.

The Countermovement Jump:

While keeping their hands on their hips, subjects were required to flex at the ankle knee and hip until a self-selected depth was achieved. Subjects then forcefully extended through ankle, hip and knee in order to try and jump as high as possible. Three repetitions were performed with a self-selected rest between repetitions. Figure 4 shows the start position, middle and end position of the CMJ.

Figure 4.

The Lunge:

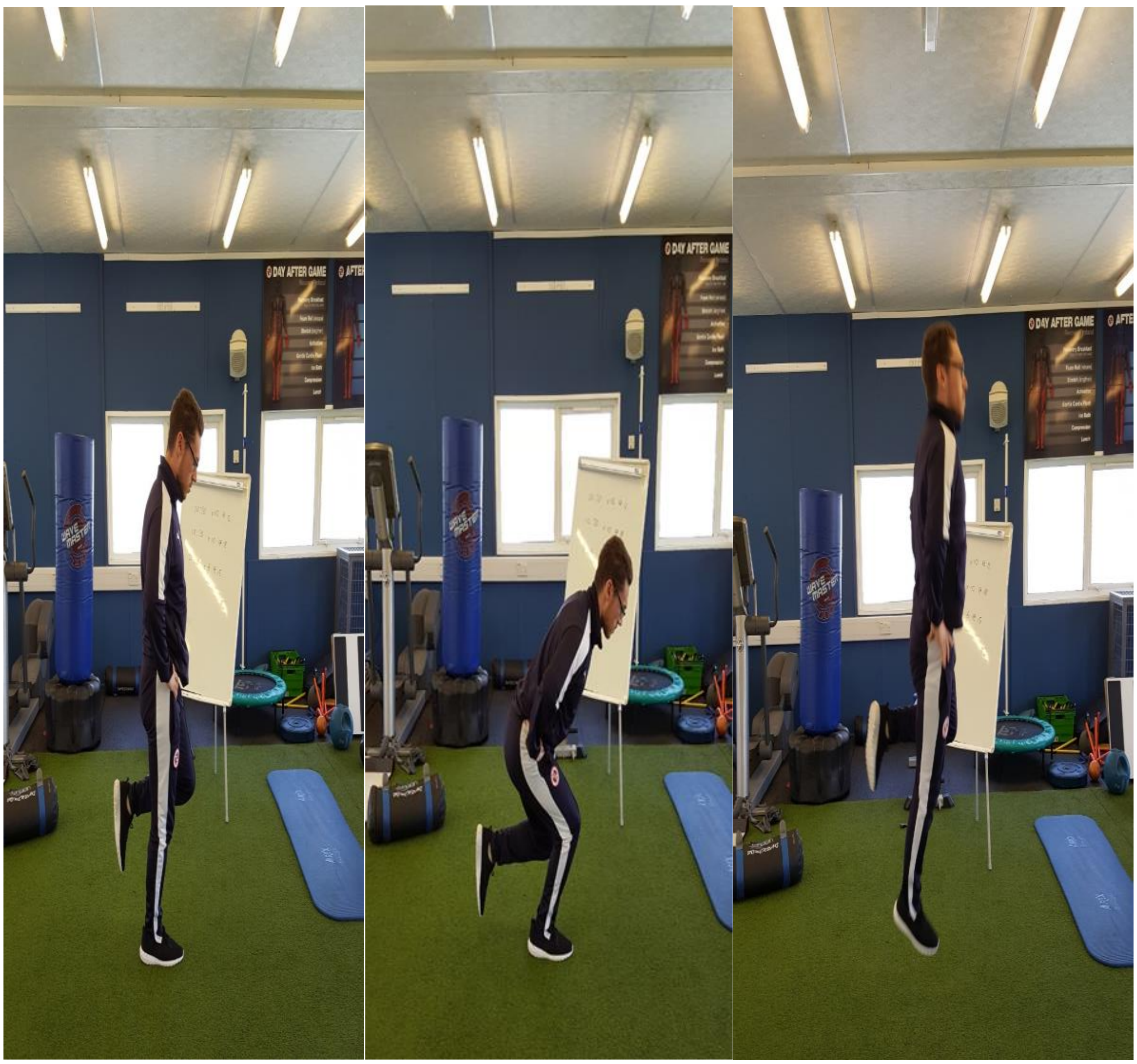
Subjects stood a self-selected distance to the left of the force plate. While keeping hands on hips, subjects were asked to take a big step forward placing their right foot onto the force platform and lowering their body as far as possible. Subjects returned to the starting position by extended through hip, knee and ankle. Three repetitions were performed with a self-selected rest between repetitions. Figure 5 displays the technique of the lunge.

Figure 5.

The Single Leg Countermovement Jump:

The SLCMJ was performed in the same way as the CMJ but using the right leg only. Three repetitions were performed with a self- selected rest between repetitions. Figure 6 shows the start, flight phase and end position during the SLCMJ exercise.

Figure 6.

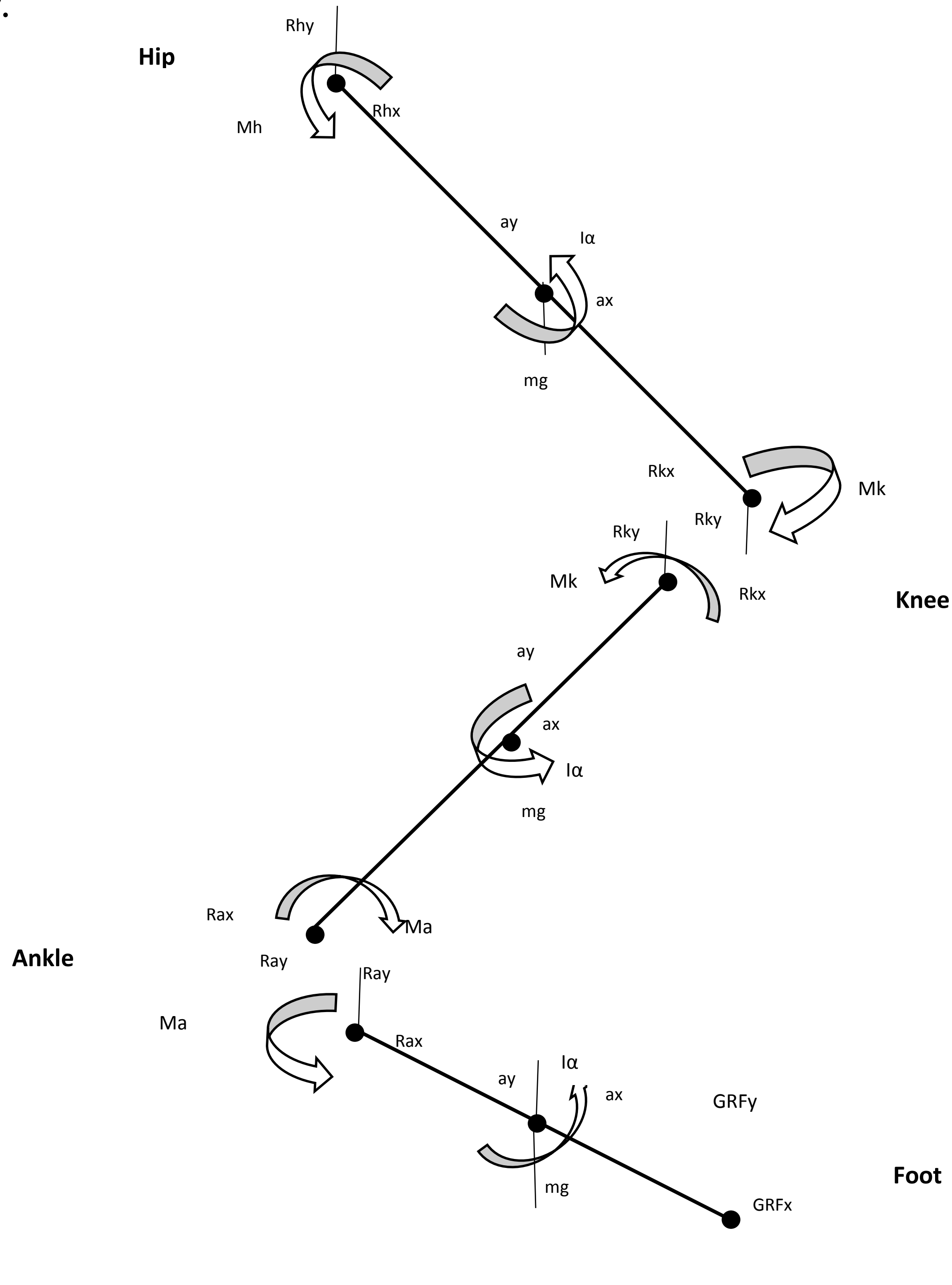


Only the propulsion phase of each exercise was used for analysis. The propulsion phase was defined in the jumping and lunge exercises between the peak ground reaction force and take off, which was selected manually by the author. For the other exercises, the propulsion phase was defined between the peak ground reaction force and the point where the force returned to body weight. Of the three repetitions recorded, only one repetition was used for analysis. This was determined by comparing the peak ground reaction forces of the three repetitions and selecting the repetition with the highest one. The right leg was used for analysis as this was the preferred kicking leg of all the subjects in this study.

Inverse Dynamics Analysis

A 2-D rigid link segment model was used for the IDA in this study (Figure 7). Using Newton-Euler equations, accurate segment angles and angular accelerations, the net joint moments from a distal to proximal direction along the kinetic chain was predicted. The accuracy and reliability of such an analysis has been discussed elsewhere (4). Both 2-D and 3-D models have been used in previous research. While a 3-D model allows moments to be calculated in the frontal, transverse and sagittal planes, movement in the sagittal plane appears to present the greatest proportion of muscle moments (5). Escamilla et al. (8) identified that the further a joint moves away from the sagittal plane the more erroneous the measure for that joint in a 2-D analysis. In their study a 2-D model overestimated knee joint angles when the joint moved in a frontal and transverse plane, however once the knee moved in the sagittal plane only, they found no significant differences among 2-D and 3-D analysis.

Figure 7.



The foot was measured from the ankle joint centre to the second metatarsal, the shank was from the knee joint centre to the ankle joint centre, the thigh was from the knee joint centre to the hip joint centre and the trunk was from the shoulder joint centre to the hip joint centre. The combination of the ground reaction forces, filtered co-ordinated data and anthropometric data were used to solve the 2-D IDA model for each joint. Anthropometric data was taken from De Leva (7) and Winter (30). Firstly the filtered co-ordinated data was used to calculate angular acceleration of each segment as well as the acceleration of the centre of mass. Next the force and moment acting on the distal segment, the foot, was calculated. Lastly net joint moments of each joint was calculated using Newton-Euler equations of motion from one segment to the next working distally to proximally. Each of the equations used are displayed below.

(1) $COMx = Xd - (Xp - Xd) * \%\ length\ of\ segment\ for\ COM$

(2) $COMy = Yd - (Yp - Yd) * \%\ length\ of\ segment\ for\ COM$

(3) $\omega_{COM} = (COMx{+}1 - COMx{-}1) / (\Delta t)$

(4) $\alpha_{COM} = (\Delta\omega) / (\Delta t)$

(5) *Segment angle = ATAN(Xd – Xp) / (Yd – Yp)*

(6) *Net joint moment = Iα – MOMxd – MOMyd – MOMxp – MOMyp*

Equations 1 and 2 are used to calculate the location of the centre of mass (COM) in the (x, y) coordinate system. Equations 3 and 4 are used to calculate the velocity and acceleration of the COM respectively. Equations 5 and 6 calculate the segment angle and the net joint moment of a joint respectively. COMx = location of the centre of mass in the x direction, COMy = location of the centre of mass in the y direction, % length of segment COM was taken from De Leva (7), Xd, Yd = coordinates of the distal joint, Xp, Yp = coordinate of the proximal joint, ω= angular velocity, α = angular acceleration, $\Delta\omega$ = rate of change in angular displacement, Δt = rate of change in time, I =

inertia of segment and MOM = moments. The segment angles were calculated using an inverse tan-1 function in excel.

The net joint moment represents the combined intersegmental moments acting on the joint at a given time. All moment values are normalized to subjects' mass. Once the net joint moments of the hip and knee was acquired, a hip: knee ratio was used to distinguish between hip and knee dominant athletes. A score >1.1 demonstrated hip dominance, a score <0.9 was knee dominant while a score between 0.9 and 1.1 was balanced. The ratio between hip and knee was later analysed across all exercises to determine if an athlete was hip or knee dominant.

Statistical Analysis

Statistical analysis was performed using IBM SPSS Statistics (Version 22, IBM Corp: Armonk, NY). A 2x5 repeated measures ANOVA (joint moment X exercise) with Bonferroni adjusted post hoc t-tests was used to compare differences among joint moments (hip or knee) and exercises (CMJ, lunge, SLCMJ, deadlift and goblet squat). A one way repeated measures ANOVA with Bonferroni adjusted post hoc tests was used to compare hip: knee ratios among all the exercises. P was set to 0.05 as a priori.

Chapter 3

RESULTS

Hip: knee ratios

Mean hip: knee ratios for all exercises are presented in Table 1. Statistical analysis revealed hip: knee ratios to be significantly affected by exercise ($F[1.1, 7] = 9.93$, $p < 0.01$). The largest hip: knee ratio was seen in the lunge exercise, however Bonferroni post hoc analysis revealed no significant differences between mean hip: knee ratios and CMJ, lunge, SLCMJ, deadlift and squat exercises. The first loading strategy found was a hip dominant strategy (i.e. hip moments 10% greater than knee moments) which was observed in all subjects for the lunge exercise. The second was a knee dominant strategy (i.e. knee moments 10% greater than hip moments) for the rest of the exercises.

Table 1.

Exercise	Hip: knee ratio
CMJ	0.68±0.11
Lunge	2.52±1.41*
SLCMJ	0.54±0.14
Deadlift	0.84±0.20
Goblet Squat	0.94±0.38

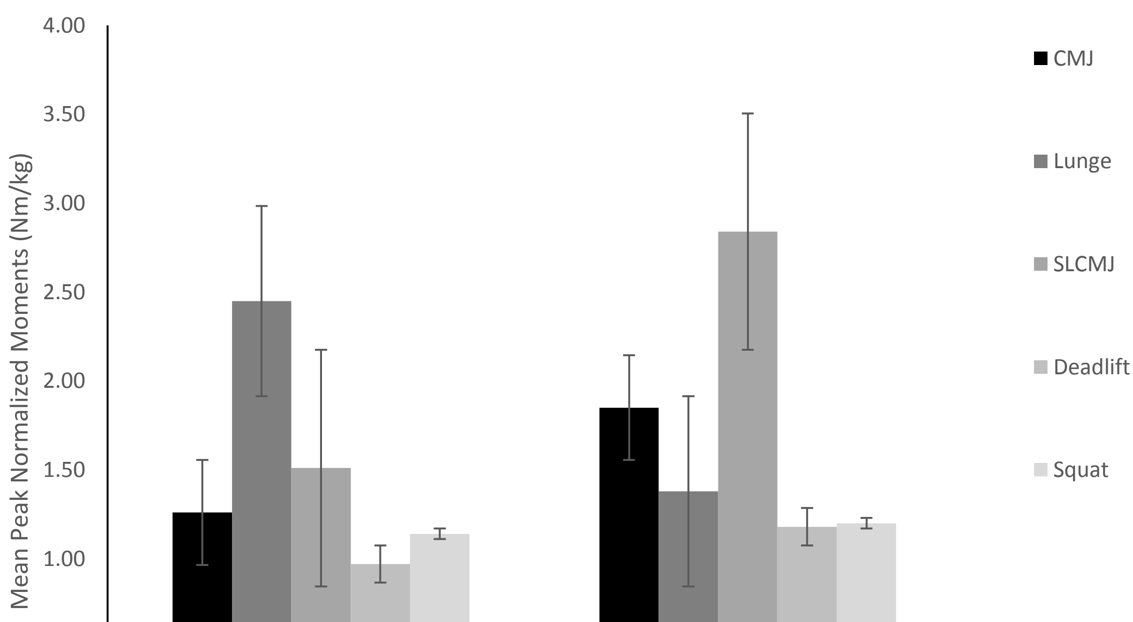
CMJ = countermovement jump, SLCMJ = single leg countermovement jump

* Significant difference when compared to all other exercises (p<0.05)

Peak mean net joint moments

Figure 8 displays the results for the differences between peak mean net joint moments of the hip and knee. The mean peak hip moment scores of the subjects were significantly greater in lunge compared to the CMJ, deadlift and squat. The mean knee moment scores of participants in the SLCMJ was significantly higher compared to the knee moments experienced in the squat and deadlift. An increase in load may have favoured a more knee dominant loading pattern to achieve maximal jump height in this cohort. Peak mean net joint moments showed no significant main effect for joint, ($F[1,6] = 5.064$, $p > 0.05$), although there was a trend towards significance ($p = 0.068$). Analysis revealed a significant main effect for exercise, ($F[4,24] = 17.131$, $p < 0.01$). Mauchly's test of sphericity was not violated for the interaction between joint and exercise therefore sphericity was assumed. This means that the variances that occurred among the pairs of groups were equal, thus providing a more realistic F ratio which in turn reduces a type 2 error. Significant interaction main effects was observed for joint and exercise, $F[4,24] = 9.305$, $p < 0.01$, and is represented by Figure 8.

Figure 8.



Loading sequence

Figures 9-13 displays the mean peak normalized moments for the hip and knee joint over the ascending phase of each exercise for subject 1. Although ankle moments are not displayed, a proximal to distal pattern was observed in the CMJ and SLCMJ exercises. During the lunge the peak hip moment occurred at the terminal end of the ascending phase while the knee maintained a near constant peak moment throughout the exercise. The squat and deadlift exercise were both seen to be the more balanced exercises of them all.

Figure 9.

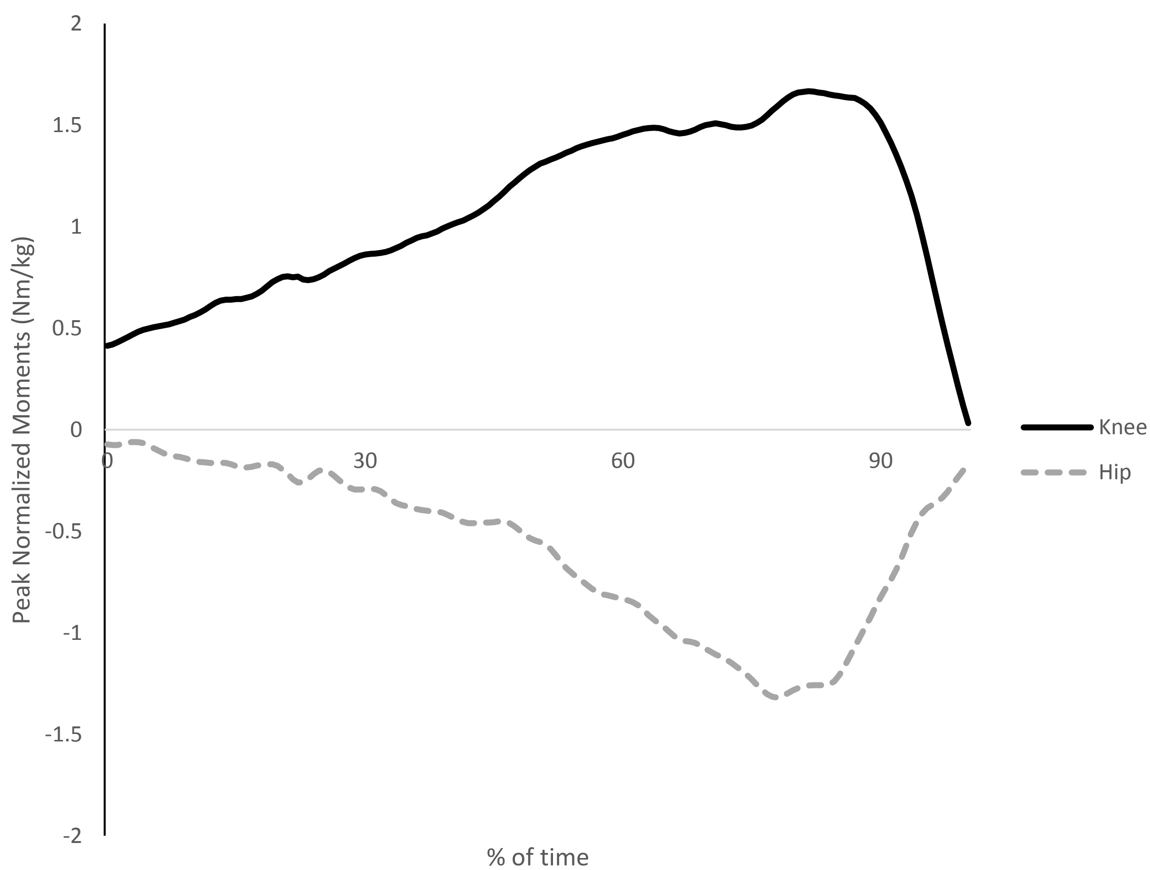


Figure 10.

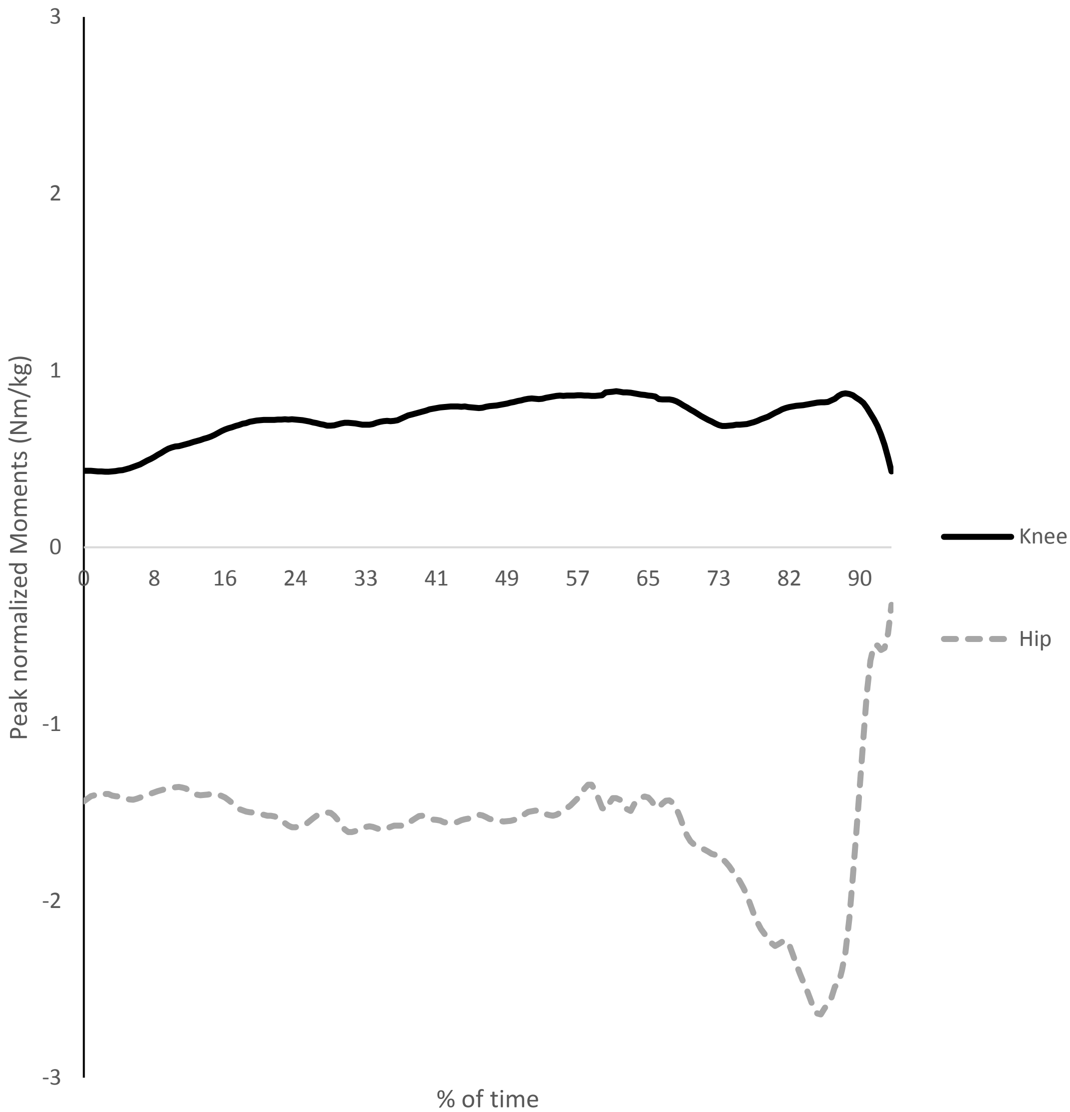

3
2
1
0
-1
-2
-3
Peak normalized Moments (Nm/kg)
0
8
16
24
33
41
49
57
65
73
82
90
% of time
Knee
Hip

Figure 11.

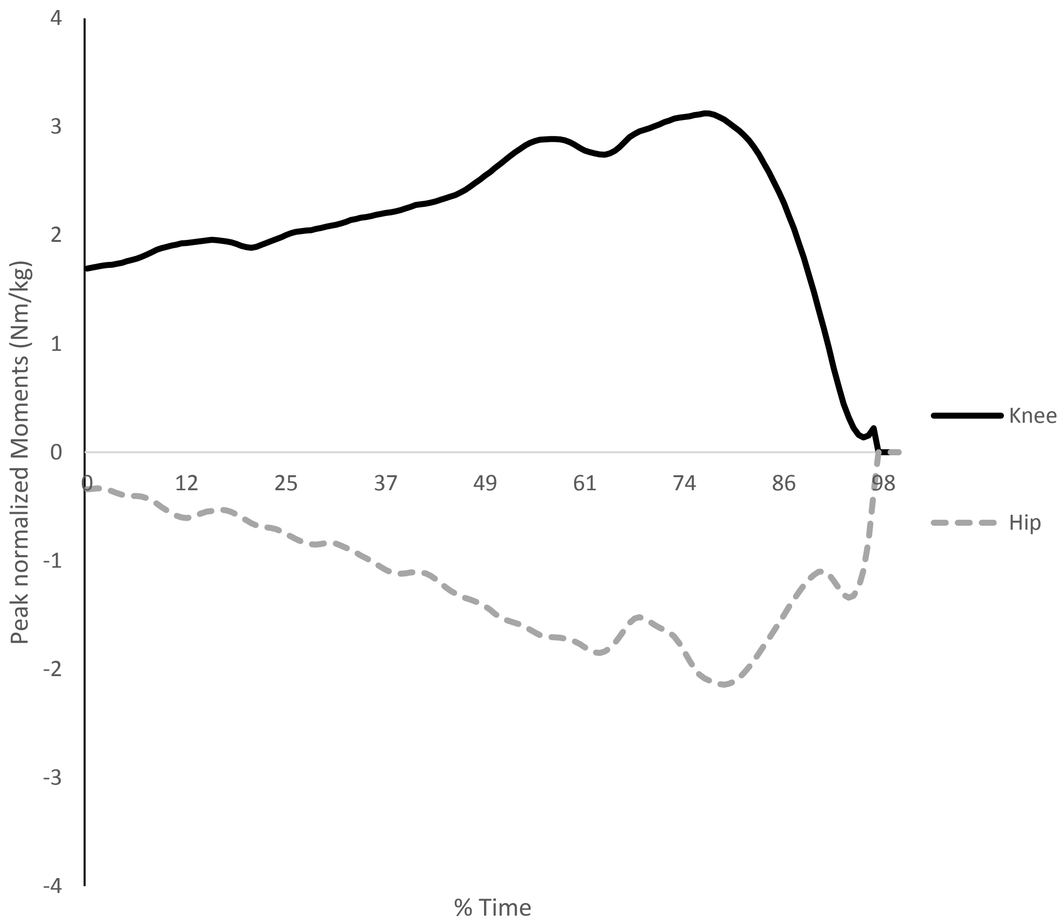

4
3
2
1
0
-1
-2
-3
-4
0
12
25
37
49
61
74
86
98
Peak normalized Moments (Nm/kg)
% Time
Knee
Hip

Figure 12.

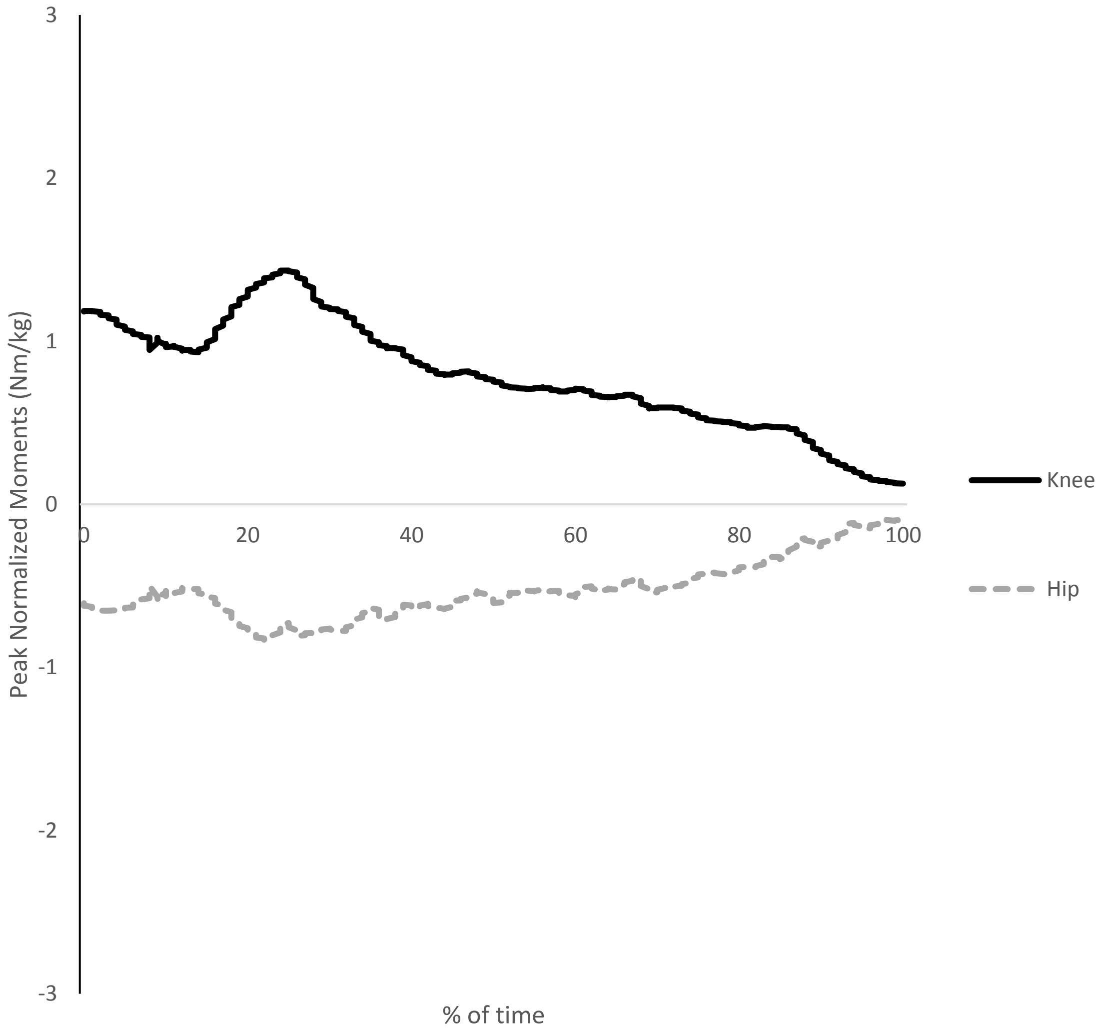
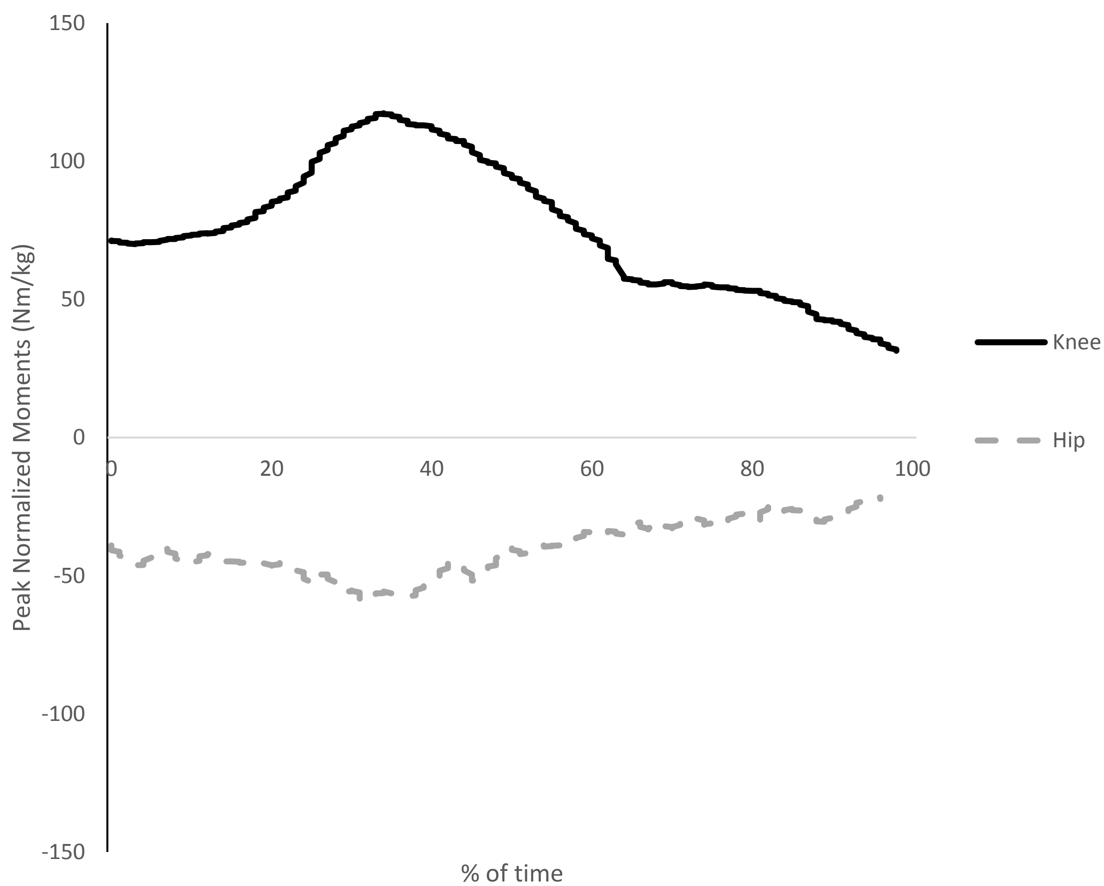

3
2
1
0
-1
-2
-3
Peak Normalized Moments (Nm/kg)
0
20
40
60
80
100
% of time
Knee
Hip

Figure 13.


150
100
50
0
-50
-100
-150
Peak Normalized Moments (Nm/kg)
0
20
40
60
80
100
% of time
Knee
Hip

Chapter 4

DISCUSSION

In the current study the intersegmental moments were calculated for the hip and knee across various exercises and then divided into each other to create a hip: knee ratio which can be used by coaches to easily understand the common loading pattern of their athletes. The main finding in this study was that subjects performed the exercises in a uniform manner rather than demonstrating inter-individual differences like first thought. The hypothesis that subjects would perform the exercises in either a hip or knee dominant strategy can be rejected. The results of this study showed that subjects loaded either the hip or knee more based on the exercise they were performing, rather than because of their own specific strategy. Depending on the technique used during the exercise, this impacted the differences found between hip and knee moments in this study. All exercises, except the lunge, showed similar loading strategies, which was a knee dominant one, while the lunge was a hip dominant exercise. A second finding in this research was that an increased load during a single leg movement increased moments about the knee. Specifically the SLCMJ produced the highest knee moments compared to all other exercises but was found only to be significantly different from the squat and deadlift. A final finding in this study was that the exercises produced a proximal to distal sequencing pattern which is shown in Figures 9-13.

Hip: knee ratios were found to be consistently the same across all subjects. As mentioned before little research has looked at analysing hip: knee ratios and its application by coaches is uncommon.

Of the research that has analysed hip: knee ratios they have indicated that variability among athletes does exist (5, 26). Cleather, Goodwin and Bull (5) selected specific examples from their study to demonstrate this. When comparing the mechanical similarity among active males between the countermovement jump and jerk, it was found that five subjects performed a countermovement jump with a knee dominant strategy (i.e. hip: knee ratio <0.90). Three athletes were hip dominant jumpers (i.e. hip: knee ratio >1.10) while four athletes were balanced jumpers (i.e. hip: knee ratio between 0.90 and 1.10). Further to this, Salem, Salinas, and Harding (26) also found differences in hip: knee ratios used by their subjects. When examining limb specific loading strategies in patients who had previous anterior cruciate ligament (ACL) reconstruction it was found that the non-injured limb displayed a more balanced hip and knee loading strategy, whereas the previously injured limb increased hip: knee ratio by 43% to a more hip dominant strategy. There was a lack of differences found between hip: knee ratios among the subjects in this study which means that all the subjects loaded their joints in a similar way. All subjects relied heavily on the production of knee moments during the exercises rather than hip moments which may be a representative of the cohort used.

A knee dominant strategy may be a representation of the preferred loading pattern of the sport the subjects are involved in. The subjects used in this study were all football players and it is possible that the uniform loading pattern observed was due to the nature of the sport rather than individual differences. It has been suggested that long term training within a specific sport can result in specific adaptations to muscle mechanics and muscle coordination that relate to that sport (15). Rousanoglou, Georgiadis and Boudolos (23) found that volleyball players' knee extensor strength showed a strong to moderate relationship with jump height. In contrast track and field athletes' knee extensor strength did not correlate well with jump height. This suggests that differences existed between the two populations and that volleyball players used a more knee dominant strategy compared to track and field athletes. In contrast, Cleather et al., (5) used subjects from various sports which may have caused the variation observed between hip and knee dominant jumpers. Jumping movements in both volleyball and football need to occur within a limited time, with most movements requiring the player to keep their head and chest up to focus on the ball and opposing players, which can restrict action about the hip. It is possible that the subjects in these sports have learned a more knee dominant approach to skills such as jumping compared to other athletes, like those used in Cleather et al., (5), who were a mixture of athletes from different sports.

Research has indicated that by performing a movement with a more upright posture, the loading pattern at each joint will subsequently change (13, 21, 27, 28). Each of these studies restricted the movement during an exercise in such a way that caused changes in the moments acting on each joint. When knee angles were restricted (i.e. knees were prevented from moving forward) during a squat exercise, hip moments increased significantly and the exercise changed from a knee dominant exercise to a hip dominant one. When the knee was not restricted during the squat exercise greater knee moments were evident compared to hip moments across all studies. Fry, Smith and Schilling (13) found that knee moments decreased from 150±50.80 Nm to 117±34.20 Nm while hip moments increased from 28.2±60 Nm to 302±71.20 Nm after the squat movement was restricted. In support of this finding Lorenzetti et al. (21) found similar loading patterns during their research. Without using any load, they found that knee moments remained the same during unrestricted and restricted squats 0.59±0.10 Nm/kg and 0.54±0.10 Nm/kg, respectively. Hip moments significantly increased from 0.31±0.11 Nm/kg to 0.48±0.13 Nm/kg when the knees were restricted from moving forward passed the toes. During a more explosive movement like the CMJ, Vanrenterghem et al., (28) also related a change in moments acting on a joint with a change in technique. In this study, they restricted trunk inclination in their subjects and compared it with normal jumps. With a reduction in forward trunk lean, it was found that knee moments increased significantly throughout the movement and when the trunk was free to bend, they established a greater increase in hip moments. The results of these studies indicate that differences in technique used by subjects caused differences in the loading pattern at each joint. The differences found between the lunge, squat and deadlift, therefore, can be explained by the differences in techniques used for the exercises. It was speculated at the beginning of the study that subjects would adopt different loading strategies within each exercise as a result of them performing the exercises differently, however this was not proven to be true. During both the squat and deadlift exercises subjects held the external load in front of their body which restricted trunk inclination and thus causing a more knee dominant loading strategy. The way in which an athlete performs a movement, therefore, can affect the relative joint contributions at each joint. Previous research therefore suggests that by performing exercise with a more upright trunk will result in more moments at the knee. None of the exercises used in this study restricted the subject's movement about the hip, however all of the subjects performed these exercises, except the lunge, using a knee dominant strategy. As suggested earlier this may be a reflection of the sports specific movement patterns that the subjects used in this study have learned over long term training and playing.

Previous research using internal kinetic analysis have concluded that the forward lunge is a hip dominant exercise (12,23). Riemann, Lapinski, Smith and Davies (23) showed that the forward lunge had the biggest contribution significantly from the hip, 62%, compared to 17% from the knee despite the knee going through a greater range of motion. More specifically the lunge was shown to be a hip extensor exercise (12). Flanagan, Wang, Greendale, Azen and Salem (12) supports the research of Riemann et al., (23) in their biomechanical study on the forward lunge. They found the hip moments to be significantly greater than the knee during the ascending phase, 1.31±0.36 Nm/kg and 0.81±0.22 Nm/kg respectively. The lunge exercise in this study was also found to be a hip dominant exercise with significantly higher hip: knee ratio between all subjects compared to any other exercise observed. This research found that on average the hip moments were twice as much as knee moments during the bodyweight lunge. The results for the lunge exercise in this study are consistent with that of recent literature and supports that the lunge is a hip dominant exercise. Figures 9-13 showed that a proximal to distal timing pattern was found between the exercises used in this study. Bobbert Mackay, Schinkelshoek, Huiijing and van Ingen Schenau (1) suggested that this segmental rotation sequencing is an optimal strategy in order to produce the greatest velocities for exercises such as jumping. It is likely that the subjects in this study used the appropriate recruitment strategy to maximally produce triple extension forces from the hip through to the ankle.

The SLCMJ was the only exercise in this study that increased the load demands on the subjects. Although load was increased indirectly, the SLCMJ caused the largest peak knee moments compared to any other exercise but was only found to be significantly larger than the deadlift and squat. The increased load had a significant impact on the loading about each joint. Research tells us that the degree of dynamic correspondence of an exercise can change depending on the load lifted during the exercise. Cushion, Goodwin and Cleather (6) found that at higher loads for the push jerk exercise, 30% and 50% 1 repetition maximum (RM), a closer degree of mechanical similarity was observed towards the countermovement jump. More specifically an increased loading at the knee joint, at these loads, was found which significantly correlated to CMJ performance, (r=0.75 and r=0.80) respectively. In this study the SLCMJ produced the greatest peak knee joint moments compared to any other exercise. It is plausible to suggest that an increase in load favoured a more knee dominant strategy in these athletes. However, a study by Flanagan and Salem (10) contradicts this idea. When analysing the back squat exercise subjects were subjected to four different loads, 25%, 50%, 75% and 100% 1RM. At 25% 1RM knee and hip joint moments were 1.35±0.34 Nm/kg and 2.05±0.36 Nm/kg respectively. The authors found that with increasing loads increased the moments about each joint. Further to this, at 100% 1RM the hip moment increased to a far greater extent than the knee moments, 4.89±0.76 Nm/kg and 1.97±.043 Nm/kg respectively. It is clear that in this exercise the subjects favoured higher loading of the hips compared to the knee at maximum load. This is the opposite trend which was observed by Cushion et al (6), where they acquired that hip moments decrease as the load increased during the push jerk. During the push jerk exercise the barbell is placed on the anterior deltoids, which restricts movement at the hip therefore at increasing loads athletes must further utilize their knees rather than their hips to perform the skill. In this study athletes were free from any technique restriction during the SLCMJ, and an increased knee moment was found. The SLCMJ exercise can therefore be used as an exercise to improve loading at the knee in athletes. The effect that increasing loading at the knee would have on performance needs further investigation.

It is essential for the reader to comprehend the limitations of this study and to take note of the influence these drawbacks may have on the findings presented. Firstly, the internal validity of applying the reflective markers to the subjects was reduced. The markers were placed on the anatomical landmarks by estimating the joint centre rather than using accurate measuring. It was therefore difficult to ensure exact locations were utilised on all subjects due to the lack of precision applying reflective markers. Consequently, the resultant net joint moments calculated in this study may therefore be inaccurate and may be either too high or too low for a certain joint. For example, on one subject the length of the foot was said to be 10cm long, which clearly underestimated foot length. This in turn resulted in errors when calculating centre of mass location and centre of pressure location. The effect that these errors had on the results brought about inaccuracies in the net joint moment at each joint. Moments are caused by the product of force and the perpendicular distance from a reference point, in this case the centre of mass. Using the example of the foot measuring only 10cm, the moments that were calculated at the ankle may have been underestimated for this subject. This would have a knock on effect leading to further inaccurate knee and hip moment scores. Finally, the force plate that was used during the study was a single axis force plate, therefore, only measured force in the vertical direction. The IDA model requires both force in the vertical and horizontal direction in order to provide an accurate net joint moment at each joint. Although the force that is normally seen in the horizontal direction is relatively small, this may have affected the calculation of the centre of pressure, as the horizontal force should have been used to accurately predict centre of pressure location.

The results of this study suggest that differences exist between the internal joint loading patterns of commonly used gym based exercises. Previous research has suggested that inter-individual differences are found within exercises but that was not observed in this study. The limitations outlined earlier had an impact on the accuracy of these findings, thus, it is difficult to apply these findings in a real world setting. However, this study has highlighted that internal kinetics analyses can aid coaches understanding of the mechanical differences between exercises and sports skills.

Chapter 5

PRACTICAL APPLICATIONS

The results of this study suggest that coaches need to be aware of the specific movement patterns, specifically the kinetics, of their athletes so that they can safely design more appropriate training programmes. Coaches need to understand that the joint contribution among athletes during exercises may vary depending on the sport they play in or even the strengths and weaknesses of the athlete. It is unclear as to what impact further increasing knee moments in a knee dominant athlete will have on performance and whether trying to change this strategy to a hip dominant one would cause any alterations in performance. Finally it is clear that by restricting movement about the hip, greater knee moments are produced. Coaches should bear this in mind when they wish to either increase knee moments or hip moments in their programmes.

REFERENCES

1. Bobbert, MF, Mackay, M, Schinkelshoek, D, Huijing, PA, and van Ingen Schenau, GJ. Biomechanical analysis of drop and countermovement jumps. *Eur J Appl Physiol* 54: 566-573, 1986.
2. Bobbert, MF, Huijing, PA, and van Ingen Schenau, GJ. Drop jumping: I. The influence of jumping technique on the biomechanics of jumping. *Med Sci Sports Exerc* 19: 332-338, 1987a.
3. Cholewicki, J, McGill, SM, and Norman, RW. Lumbar spine loads during the lifting of extremely heavy weights. *Med Sci Sports Exerc* 23: 1179-1186, 1991.
4. Cleather, D, and Bull, A. Influence of inverse dynamics methods on the calculation of inter-segmental moments in vertical jumping and weightlifting. *Biomed Eng Onl* 9-74, 2010.
5. Cleather, D, Goodwin, J, and Bull, A. Intersegmental moment analysis characterizes the partial correspondence of jumping and jerking. J Strength Cond Res 27: 89-100, 2013.
6. Cushion, EJ, Goodwin, JE, and Cleather DJ. Relative intensity influences degree of correspondence of jump squats and push jerks to countermovement jumps. J Strength Cond Res, 30: 1255-1264, 2016.
7. De Leva, P. Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. Journal Biomech 29: 1223-1230, 1996.
8. Delextrat, A, Gregory, J, and Cohen, D. The use of functional H: Q ratio to assess fatigue in soccer. *Int J Sports Med* 31: 192-197, 2010.
9. Escamilla, RF, Francisco, AC, Fleisig, GS, Barrentine, SW, Welch, CM, Kayes, AV, Speer, KP, and Andrews, JR. A three-dimensional biomechanical analysis of sumo and conventional style deadlifts. Med Sci Sports Exerc 32: 1265-1275, 2000.

10. Escamilla, RF, Fleisig, GS, Lowry, TM, Barrentine, SW, and Andrews, JR. A three-dimensional biomechanical analysis of the squat during varying stance widths. Med Sci Sports Exerc 33: 984-998, 2001.
11. Flanagan, SP, and Salem, G. Lower extremity joint kinetic responses to external resistance variations. J Appl Biomech 24: 58-68, 2008.
12. Flanagan, SP, Wang, M, Greendale, GA, Azen, SP, and Salem, GJ. Biomechanical attributes of lunging activities in older adults. J Strength Cond Res 18: 599-605, 2004.
13. Fry, A, Smith, J, and Schilling, B. Effect of knee position on hip and knee torques during the barbell squat. J Strength Cond Res 17: 629–633, 2003.
14. Gullett, JC, Tillman, MD, Gutierrez, GM, and Chow, JW. A biomechanical comparison of back and front squats in healthy trained individuals. J Strength Cond Res 23: 284-292, 2008.
15. Goodwin, J. Maximum velocity is when we can no longer accelerate: using biomechanics to inform speed development. *UKSCA* 21: 3-9, 2011.
16. Hubley, CL, and Wells, RP. A work-energy approach to determine individual joint contributions to vertical jump performance. Eur J Appl Physiol 50: 247-254, 1983.
17. Izquierdo, M, Hakkinen, K, Gonzalez-Badillo, Jj, Ibanez, J, and Gorostiaga, EM. Effects of long term training specificity on maximal strength and power of the upper and lower extremities in athletes from different sports. *Eur J Appl Physiol* 87: 264-271, 2002.
18. Jacobs, R, and Van Ingen Schenau, GJ. Intermuscular coordination in a sprint push-off. Journal Biomech 25: 953- 965, 1992.
19. Jacobs, R, Bobbert, MF, and van Ingen Schenau, GJ. Mechanical output from individual muscles during explosive leg extensions: the role of biarticular muscles. Journal Biomech 29: 513-523, 1996.

20. Johnson, MD, and Buckley, JG. Muscle power patterns in the mid-acceleration phase of sprinting. J Sports Sci 19: 263-272, 2001.

21. Lorenzetti, S, Gulay, T, Stoop, M, List, R, Gerber, H, Schellenberg, F, and Stussi, E. Comparison of the angles and corresponding moments in the knee and hip during restricted and unrestricted squats. J Strength Cond Res 26: 2829-2836, 2012.

22. Mackala, K, Stodolka, J, Siemienski, A, and Coh, M. Biomechanical analysis of squat jump and countermovement jump from varying starting positions. J Strength Cond Res 27: 2650-2661, 2013.

23. Riemann, BL, Lapinski, S, Smith, L, and Davies, G. Biomechanical analysis of the anterior lunge during 4 external-load conditions. Journal of Athletic Training 47: 372-378, 2012.

24. Robertson, DGE, Wilson, JMJ, and St. Pierre, TA. Lower extremity muscle functions during full squats. J Appl Biomech 24: 333-339, 2008.

25. Rousanoglou, EN, Georgiadis, GV, and Boudolos, K. Muscular strength and jumping performance relationships in young women athletes. *J Strength Cond Res* 22: 1375-1378, 2008.

26. Salem, GJ, Salinas, R, and Harding, VF. Bilateral kinematic and kinetic analysis of the squat exercise after anterior cruciate ligament reconstruction. Arch Phys Med Rehabil 84, 1211-1216, 2003.

27. Swinton, PA, Lloyd, R, Keogh, JWL, Agouris, I, and Stewart, AD. A biomechanical comparison of the traditional squat, powerlifting squat, and box squat. J Strength Cond Res 26: 1805-1816, 2012.

28. Vanrenterghem, J, Lees, A, and Clercq, DD. Effect of forward trunk inclination on joint power output in vertical jumping. J Strength Cond Res, 22: 708-71, 2008.

29. Vanrenterghem, J, Lees, A, Lenoir, M, Aerts, P, and Clercq, DD. Performing the vertical jump: movement adaptations for submaximal jumping. Hum Move Sci 22: 713-727, 2004.

30. Verkhoshansky, YV. Special Strength Training. Michigan: Ultimate: Athlete Concepts, 2006.

31. Winter, DA. Biomechanics and motor control of human movement. 4th Ed. Wiley, NJ, USA, 2009.

32. Wu, G, Siegler, S, Allard, P, Kirtley, C, Leardini, A, Rosenbaum, D, Whittle, MD, Lima, D, Cristofolini, L, Witte, H, Schmid, O, and Stokes, I. ISB recommendation on definitions of joint coordinate systems of various joints for the reporting of human joint motion—Part I: Ankle, hip, spine. Journal Biomech 35: 543– 548, 2002.

33. Wu, G, van der Helm, FC, Veeger, H, Makhsous, M, Van Roy, P, Anglin, C, Nagels, J, Karduna, A, McQuade, K, Wang, X, Werner, F, and Buchholz, B. ISB recommendation on definitions of joint coordinate systems of various joints for the reporting of human joint motion-Part II: Shoulder, elbow, wrist and hand. Journal Biomech 38: 981-982, 2005.

Appendix I

Signed ethics application

St Mary's University Twickenham London

St Mary's University

Ethics Sub-Committee

Application for Ethical Approval (Research)

This form must be completed by any undergraduate or postgraduate student, or member of staff at St Mary's University, who is undertaking research involving contact with, or observation of, human participants.

Undergraduate and postgraduate students should have the form signed by their supervisor, and forwarded to the School Ethics Sub-Committee representative. Staff applications should be forwarded directly to the School Ethics Sub-Committee representative. All supporting documents should be merged into one PDF (in order of the checklist) and clearly entitled with your **Full Name, School, Supervisor.**

Please note that for all undergraduate research projects the supervisor is considered to be the Principal Investigator for the study.

If the proposal has been submitted for approval to an external, properly constituted ethics committee (e.g. NHS Ethics), then please submit a copy of the application and approval letter to the Secretary of the Ethics Sub-Committee. Please note that you will also be required to complete the St Mary's Application for Ethical Approval.

Before completing this form:

- Please refer to the **University's Ethical Guidelines**. As the researcher/ supervisor, you are responsible for exercising appropriate professional judgment in this review.
- Please refer to the Ethical Application System (Three Tiers) information sheet.
  - Please refer to the Frequently Asked Questions and Commonly Made Mistakes sheet.
  - If you are conducting research with children or young people, please ensure that you read the **Guidelines for Conducting Research with Children or Young People**, and answer the below questions with reference to the guidelines.

Please note:

In line with University Academic Regulations the signed completed Ethics Form must be included as an appendix to the final research project.

Approved by the Ethics Sub-Committee on the 30th April 2014.

If you have any queries when completing this document, please consult your supervisor (for students) or School Ethics Sub-Committee representative (for staff) .

St Mary's University Twickenham London

St Mary's Ethics Application Checklist

The checklist below will help you to ensure that all the supporting documents are submitted with your ethics application form. The supporting documents are necessary for the Ethics Sub-Committee to be able to review and approve your application.

Please note, if the appropriate documents are not submitted with the application form then the application will be returned directly to the applicant and may need to be re- submitted at a later date.

	Enclosed? (delete as appropriate)		Version No
Document	Yes	Not applicable	
1.Application Form	Yes		
2.Risk Assessment Form	Yes		

3.Participant Invitation Letter		Not Applicable	
4.Participant Information Sheet	Yes		
5.Participant Consent Form	Yes		
6.Parental Consent Form		Not Applicable	
7.Participant Recruitment Material - e.g. copies of Posters, newspaper adverts, website, emails		Not Applicable	
8.Letter from host organisation (granting permission to conduct the study on the premises)	Yes		
9. Research instrument, e.g. validated questionnaire, survey, interview schedule		Not Applicable	
10.DBS included		Not Applicable	
11.Other Research Ethics Committee application (e.g. NHS REC form)		Not Applicable	

I can confirm that all relevant documents are included in order of the list and in one PDF document entitled with you: ***Full Name, School, Supervisor.***

Signature of Applicant:

Signature of Supervisor:

St Mary's University Twickenham London

Ethics Application Form

1) Name of proposer(s)	John Mulroy
2) St Mary's email address	134773@live.smuc.ac.uk
3) Name of supervisor	Daniel Cleather

4) Title of project Identifying hip and knee dominant athletes using inverse dynamics

School 5) School or service of Sport, Health and Applied	St. Mary's University, The Sciences.
6) Programme (if undergraduate, postgraduate taught or postgraduate research)	MSc. Strength and Conditioning
7) Type of activity/research (staff / undergraduate student research / postgraduate student)	Postgraduate student

8) Confidentiality	
Will all information remain confidential in line with the YES/~~NO~~ Data Protection Act 1998	

9) Consent	
Will written informed consent be obtained from all participants / participants' representatives?	YES/~~NO~~

10) Pre-approved protocol	
Has the protocol been approved by the Ethics Sub-Committee under a generic application?	~~YES/NO~~/ Not applicable Date of approval:

11) Approval from another Ethics Committee	
a) Will the research require approval by an ethics committee external to St Mary's University?	~~YES~~/NO/ ~~Not applicable~~
b) Are you working with persons under 18 years of age or vulnerable adults?	~~YES~~/ NO

12) Identifiable risks	
a) Is there significant potential for physical or psychological discomfort, harm, stress or burden to participants?	~~YES~~/NO
b) Are participants over 65 years of age?	~~YES~~/NO
c) Do participants have limited ability to give voluntary consent? This could include cognitively impaired persons, prisoners, persons with a chronic physical or mental condition, or those who live in or are connected to an institutional environment.	~~YES~~/NO
d) Are any invasive techniques involved? And/or the collection of body fluids or tissue?	~~YES~~/NO
e) Is an extensive degree of exercise or physical exertion involved?	~~YES~~/NO

f) Is there manipulation of cognitive or affective human responses which could cause stress or anxiety?	~~YES~~/NO
g) Are drugs or other substances (including liquid and food additives) to be administered?	~~YES~~/NO
h) Will deception of participants be used in a way which might cause distress, or might reasonably affect their willingness to participate in the research? For example, misleading participants on the purpose of the research, by giving them false information.	~~YES~~/NO
i) Will highly personal, intimate or other private and confidential information be sought? For example sexual preferences.	~~YES~~/NO
j) Will payment be made to participants? This can include costs for expenses or time.	~~YES~~/NO If yes, please provide details
k) Could the relationship between the researcher/ supervisor and the participant be such that a participant might feel pressurised to take part?	~~YES~~/ NO

13) Proposed start and completion date

Please indicate:

- When the study is due to commence.
- Timetable for data collection.
- The expected date of completion.

Please ensure that your start date is at least 3 weeks after the submission deadline for the Ethics Sub-Committee meeting.

Data collection is due to commence over the month of February. Due to the schedule of the subjects, data collection will last around a month which means the completion date should occur around March.

14)Sponsors/Collaborators

Please give names and details of sponsors or collaborators on the project. This does not include you supervisor(s) or St Mary's University.

- Sponsor: An individual or organisation who provides financial resources or some other support for a project.

- Collaborator: An individual or organisation who works on the project as a recognised contributor by providing advice, data or another form of support.

There are no other collaborators on the project.

15. Other Research Ethics Committee Approval

- Please indicate whether additional approval is required or has already been obtained (e.g. the NHS Research Ethics Committee).
- Please also note which code of practice / professional body you have consulted for your project
- Whether approval has previously been given for any element of this research by the University Ethics Sub-Committee.

No additional approval is required for this project.

16. Purpose of the study

In lay language, please provide a brief introduction to the background and rationale for your study.

- Be clear about the concepts / factors / performances you will measure / assess/ observe and (if applicable), the context within which this will be done.
- Please state if there are likely to be any direct benefits, e.g. to participants, other groups or organisations.

Strength and conditioning coaches are faced with the task of identifying strengths and weaknesses within their athletes in order to effectively design appropriate training programs and to maximize performance and reduce injury. Throughout various movements in sport, athletes can adopt different loading patterns around their joints. For example one athlete could predominantly load their knee during various movements compared to their hip. For movements that may require more knee loading, performance from a knee dominant athlete may be enhanced. For the same movement, an athlete that predominately loads the hip may demonstrate a lower performance. Therefore, identifying how an athlete loads their joints during different movements can increase knowledge of their strengths and weaknesses for a given skill. In addition to this, understanding how different exercises load different parts of the body can help coaches plan more effective training programs by picking exercises that are more loading specific to their athletes sport.

Research seems to agree that athletes can load their joints differently during a given movement. During the squat exercise, Robertson and Winter, (1980) found that peak moments varied among subjects with the highest peak occurring at the hip. Cleather, Goodwin and Bull, (2013) identified three different loading patterns from their subjects while performing a countermovement jump. Athletes adopted either a knee dominant, hip dominant or balanced loading pattern. They suggested that athletes may opt to use either strategy depending on their strengths and weaknesses and that coaches can use this information to change this strategy in order to optimise performance. Cholemicki, McGill and Norman, (1991) also found high variability of the relative joint forces used by different lifters when performing the deadlift and sumo deadlift.

In order to find this out net joint moments need to be calculated for both the hip and knee. These net joint moments can be used to describe specific loading patterns at a particular joint. A method known as inverse dynamics, which measures the internal kinetics of a joint, is used for analysis. To the author's knowledge no study has looked at numerous exercises in order to develop a profile on individual athletes to determine whether or not they are hip or knee dominant. By investigating loading patterns across numerous exercises, it will hopefully provide a better understanding of the common loading patterns seen in this population. The aim therefore of this study is to identify whether and athlete is hip or knee dominant using inverse dynamics techniques.

The exercises that will be utilized in this study are the back squat (propulsion phase), deadlift (propulsion phase), countermovement jump (both propulsion), forward lunge (propulsion phase) and single leg countermovement jump (both propulsion). The results will aspire to allow coaches to make a better informed decision as to the type of training that will likely improve performance of their athletes. Subjects will also be able to understand how they perform each exercise and if a pattern of knee, hip or balanced strategy is evident.

17. Study Design/Methodology

In lay language, please provide details of:

a) The design of the study (qualitative/quantitative questionnaires etc.)
b) The proposed methods of data collection (what you will do, how you will do this and the nature of tests).
c) You should also include details regarding the requirement of the participant i.e. the extent of their commitment and the length of time they will be required to attend testing.
d) Please include details of where the testing will take place.
e) Please state whether the materials/procedures you are using are original, or the intellectual property of a third party. If the materials/procedures are original, please describe any pre-testing you have done or will do to ensure that they are effective.

Following a ten minute warm up, subjects will perform 3 unrestricted repetitions of each exercise. Each subject's right lower limb will be used for analysis. The right limb only must be placed on a portable force platform (PASPORT Force Platform PS-2141) during each of the repetitions to record kinetic data. Prior to being recorded reflective markers will be placed on each subject at the hip, knee, shoulder, ankle and end part of their foot. Each subject will then be recorded performing each exercise using a high speed camera (Phantom v9.0.663), from a sagittal view, that will be set up on a tripod 1.1m from the ground and positioned 17m from the centre of the force platform. For each exercise the markers at the hip, knee, shoulder, ankle and end part of their foot will be tracked using Kinovea software. Kinovea is a free to use video player than allows tracking of specific markers over time. Once recorded, the data needs to be digitized for quantitative examination. Digitizing the recorded movements provides numerical points or values so that joint displacement and acceleration can be calculated. This is achieved through the use of a known length which is visible within each video. This tells Kinovea how to relate the pixels to real world units. Speed and displacement can then be calculated through the configuration tab. These values are then exported to excel along with the ground reaction force data. Both kinetic and kinematic data are sampled at 250Hz.

Both the data from Kinovea and the data form the force plate will be entered into a 2-D linked rigid model for inverse dynamics analysis. From there net joint moments, joint impulse and power can be calculated at the knee and hip joint. All moment values are normalized to subjects' mass. Then a ratio between knee net joint moment and hip net joint moment can be determined to identify a knee dominant (>1.1), hip dominant (<0.9) or balanced (0.9-1.1) strategy during an exercise. A relationship will then be explored across all exercises to create a profile for each subject.

Each subject will only be required to perform the required number of exercises and repetitions during the testing procedure. It should take between 30-45 mins per subject to monitor, which includes subject preparation and data collection. Testing will take place in the gymnasium at Reading F.C. training ground. The testing equipment is borrowed from the biomechanics laboratory in St. Mary's University.

The Squat: While keeping their hands on their hips, subjects are required to flex at the ankle knee and hip until a self-selected max depth is achieved. Once max depth is achieved subjects return to the start position by extending through the hip, knee and ankle. Heels must remain on the ground at all times. Speed and tempo is controlled by the subjects.

The Deadlift: Subjects are required to flex at the ankle, knee and hip until they can grasp a barbell which is positioned under their center of mass. The barbell weighs 30kgs, which is very light for this subject group. While keeping arms straight, subjects must extend through the hip, knee and ankle to bring the bar off the floor. They must then flex through the hip, knee and ankle to return bar to staring position.

The Countermovement Jump: While keeping their hands on their hips, subjects are required to flex at the ankle knee and hip until a self-selected max depth is achieved. Once max depth is achieved subjects forcefully extend through ankle, hip and knee to jump as high as possible. Subjects will be asked to land softly but no other instructions on landing will be provided.

The Lunge: While keeping hands on hips, subject will be asked to step out in front of them placing their right foot onto the force platform. The distance in which subjects step out will be self-selected. They will be instructed to step out as far as possible.

The Single Leg Countermovement Jump: Same as The Countermovement jump except it is performed with the right leg only.

18. Participants

Please mention:

a) The number of participants you are recruiting and why. For example, because of their specific age or sex.
b) How they will be recruited and chosen.
c) The inclusion / exclusion criteria's.
d) For internet studies please clarify how you will verify the age of the participants. e) If the research is taking place in a school or organisation then please include their written agreement for the research to be undertaken.

10 professional football players will be recruited for this study. Subjects will be recruited from the under 21 football team at Reading F.C. Subjects will be excluded from the study if they have any current injuries. Subjects must also have prior experience of the exercises used and a training history of at least one year. Subjects range between 18-20 years of age and are in the middle of their current season. All subjects are male and weight between 65-90 kilograms.

c) The inclusion / exclusion criteria's.
d) For internet studies please clarify how you will verify the age of the participants. e) If the research is taking place in a school or organisation then please include their written agreement for the research to be undertaken.

10 professional football players will be recruited for this study. Subjects will be recruited from the under 21 football team at Reading F.C. Subjects will be excluded from the study if they have any current injuries. Subjects must also have prior experience of the exercises used and a training history of at least one year. Subjects range between 18-20 years of age and are in the middle of their current season. All subjects are male and weight between 65-90 kilograms.

19. Consent

If you have any exclusion criteria, please ensure that your Consent Form and Participant Information Sheet clearly makes participants aware that their data may or may not be used.

a) Are there any incentives/pressures which may make it difficult for participants to refuse to take part? If so, explain and clarify why this needs to be done

b) Will any of the participants be from any of the following groups?
   - Children under 18
   - Participants with learning disabilities
   - Participants suffering from dementia
   - Other vulnerable groups.

c) If any of the above apply, does the researcher/investigator hold a current DBS certificate? A copy of the DBS must be included with the application.

d) How will consent be obtained? This includes consent from all necessary persons i.e. participants and parents.

Each subject will be provided with a plain language information sheet, a consent form and a medical screening form. Details regarding the study rationale, methods and their role as participant will be provided within these forms, which they will explicitly sign and hand back. Subjects will be aware of any risks as well as any benefits that may occur from their participation in the study. Each subject will be above 18 years of age and free from any disabilities or psychological diseases.

20. Risks and benefits of research/ activity

a) Are there any potential risks or adverse effects (e.g. injury, pain, discomfort, distress, changes to lifestyle) associated with this study? If so please provide details, including information on how these will be minimised.

b) Please explain where the risks / effects may arise from (and why), so that it is clear why the risks / effects will be difficult to completely eliminate or minimise.

c) Does the study involve any invasive procedures? If so, please confirm that the researchers or collaborators have appropriate training and are competent to deliver these procedures. Please note that invasive procedures also include the use of deceptive procedures in order to obtain information.

d) Will individual/group interviews/questionnaires include anything that may be sensitive or upsetting? If so, please clarify why this information is necessary (and if applicable, any prior use of the questionnaire/interview).

e) Please describe how you would deal with any adverse reactions participants might experience. Discuss any adverse reaction that might occur and the actions that will be taken in response by you, your supervisor or some third party (explain why a third party is being used for this purpose).

f) Are there any benefits to the participant or for the organisation taking part in the research (e.g. gain knowledge of their fitness)?

This study has minimal risk to the safety and wellbeing of the participants. There is no invasive procedures required throughout data collection. Subjects are only required to perform 5 exercises at their own pace. A proper warm up prior to testing will ensure no muscle injuries may occur. The testing procedure is relatively simple and very safe so there are very minimal risks involved. In the event of an injury occurring during testing medical operating procedures from Reading F.C. will be adhered to. A physio will be on site and within 5mins of the testing location.

Subjects who take part in this study will gain further knowledge into how they load a particular joint during different exercises. This will allow them to identify whether they are hip or knee dominant. This will hopefully allow them to work on their strength sand weaknesses more effectively in the future. Feedback to the subjects will be provided alongside their 6 week reviews which will be posted on PMA, which is a site the club uses to provide feedback to the players on their performance.

21. Confidentiality, privacy and data protection

a) What steps will be taken to ensure participant’s confidentiality?

- Describe how data, particularly personal information, will be stored.
- Consider how you will identify participants who request their data be withdrawn, such that you can still maintain the confidentiality of theirs and others data.

b) Describe how you manage data using a data a management plan.

- You should show how you plan to store the data securely and select the data that will be made publically available once the project has ended.
- You should also show how you will take account of the relevant legislation including that relating data protection, freedom of information and intellectual property.

c) Who will have access to the data? Please identify all persons who will have access to the data (normally yourself and your supervisor).

d) Will the data results include information which may identify people or places?

- Explain what information will be identifiable.
- Whether the persons or places (e.g. organisations) are aware of this.
- Consent forms should state what information will be identifiable and any likely outputs which will use the information e.g. dissertations, theses and any future publications/presentations.

Subjects' identity and other personal information will not be revealed or used in any future study. Each subject will be assigned an I.D. number under which all information will be stored on a password locked computer. The researcher and supervisor will be the only people to have access to this information. The confidentiality of this information can only be protected within the limitations of the law. A copy of the data will also be kept on a stored university server. The data collected will be analysed using SPSS to determine differences among the exercises and among subjects.

22. Feedback to participants

Please give details of how feedback will be given to participants:

- As a minimum, it would normally be expected for feedback to be offered to participants in an acceptable to format, e.g. a summary of findings appropriate written.
- Please state whether you intend to provide feedback to any other individual(s) or organisation(s) and what form this would take.

Because I work within the organisation full time I will personally provide each player, along with the head of the Sport Science department with a comprehensive summary of the findings. This will include an individual report to each player letting them know if they are hip dominant, knee dominant or balanced. I will present a slideshow presentation to all Sport Science staff of the findings.

The proposer recognises their responsibility in carrying out the project in accordance with the University's Ethical Guidelines and will ensure that any person(s) assisting in the research/ teaching are also bound by these. The Ethics Sub-Committee must be notified of, and approve, any deviation from the information provided on this form.

Signature of Proposer(s)	Date:
Signature of Supervisor (for student research projects)	Date:

Appendix II

Information Sheet

St. Marys University Twickenham

Title:

Identifying between hip and knee dominant athletes using gym based exercises.

1. Introduction to the Research Study.

Previous research has identified that during a countermovement jump different athletes displayed different loading patterns. Athletes demonstrated a knee dominant loading strategy, hip dominant loading strategy or a balanced loading strategy during the exercise. This can have implications for both injury and performance. If an athlete constantly loads their knee during every movement they are at risk of overloading the knee which may cause injury. Knowing what type an athlete is, therefore, can help coaches make improved decisions regarding future program selection. Although it is unclear whether increasing hip loading on a knee dominant athlete would either improve performance or decrease the risk of injury to the knee, the

purpose of this study is to support previous work on identifying knee and hip dominant athletes.

This study will use numerous gym based exercises in order to provide more information about the common loading strategies for the subjects used.

2. Involvement in the Research Study will require

If you agree to the participation in this study you will undertake a one off battery of tests. Before testing begins you will be required to perform a warm up of 10 minutes consisting of cycling and practise of the exercises. Once the warm up is over you will have reflective markers attached to the shoulder, hip, knee and ankle on your right hand side only. You will then perform three repetitions of the squat, deadlift, countermovement jump, single leg countermovement jump and forward lunge. With each repetition, you will be required to step onto a force plate which will collect the forces you produce into the ground. You will also be recorded using a high speed camera from the side throughout the entirety of the test.

3. Potential risks from involvement in the Research Study

There are very little risks involved during this study. A proper warm up and practise of the exercises will help prevent injury during performance of the exercises. Other than that there are no other health risks involved while you take part in this study. In the case of any injury you will be given first aid treatment while a physiotherapist is called.

Benefits from involvement in the Research Study

Subjects will receive a report identifying whether they are hip or knee dominant. This should help better design future training programs for themselves. Feedback will be provided through PMA.

4. Arrangements to protect confidentiality of data

Subjects' identity and other personal information will not be revealed or used in any future study. You will be assigned an I.D. number under which all information will be stored on a password locked computer. The researcher and supervisor will be the only people to have accesto this information. The confidentiality of this information can only be protected within the limitations of the law.

5. Involvement in the Research study is voluntary

Involvement in this study is completely voluntary. You may withdraw from the research study at any given point. There will be no penalty for withdrawing before all stages are completed.

Appendix III

Consent Form

Name of Participant: ___________________________________

Title of the project: ____

Main investigator and contact details: ____________________________

Members of the research team:

1. I agree to take part in the above research. I have read the Participant Information Sheet which is attached to this form. I understand what my role will be in this research, and all my questions have been answered to my satisfaction.
2. I understand that I am free to withdraw from the research at any time, for any reason and without prejudice.
3. I have been informed that the confidentiality of the information I provide will be safeguarded.
4. I am free to ask any questions at any time before and during the study.
5. I have been provided with a copy of this form and the Participant Information Sheet.

Data Protection: I agree to the University processing personal data which I have supplied. I agree to the processing of such data for any purposes connected with the Research Project as outlined to me.

Name of participant (print)…………………………Signed………………..….Date………………

Name of witness (print)……………………………..Signed………………..….Date………………

If you wish to withdraw from the research, please complete the form below and return to the main investigator named above.

Title of Project: ____

I WISH TO WITHDRAW FROM THIS STUDY

Name: ___________________________________

Signed: _____________________________ Date: __________________